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Desiring a more versatile treatment option, an Alabama utility undertook a pilot-plant study to evaluate various coagulant doses to improve TOC removal, provide consistent floc formation, and reduce settled turbidity.

BY JEFF COCHRAN, PATTY BARRON, APRIL NABORS, AND WENDELL COX

SYSTEM OPTIMIZATION COAGULANT STUDY LEADS TO IMPROVED TREATMENT

WITH THE HELP of a state-of-the-art mobile pilot plant, the Birmingham (Ala.) Water Works Board (BWWB) evaluated four coagulants at its Shades Mountain Filter Plant (SMFP). The coagulant evaluation focused on a pH range of 5–7.4 in various combinations of coagulation polymers, flocculant aids, and preoxidants. The project's goal was to identify a process that outperformed the plant's established coagulation regime—aluminum sulfate (alum) and a coagulant aid. More than 250 coagulation conditions were tested.

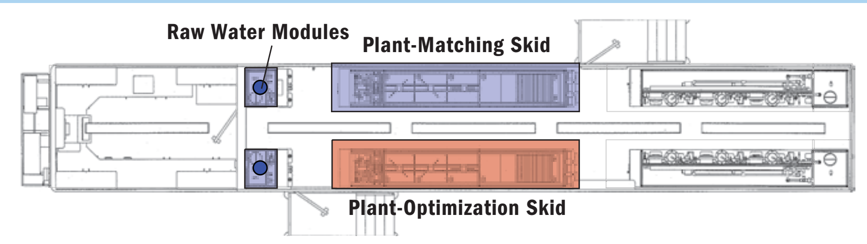
The desire to improve the plant's process arose from three problems. First, alum couldn't produce large, heavy floc that would settle during colder winter months, remain settled during wind events, or provide settled turbidities less than 1.0 ntu. Second, utility personnel wanted to identify a versatile coagulant that could work with a wider range of raw water turbidities, total organic carbon (TOC), and alkalinities and improve settled turbidities. Third, plant personnel wanted the coagulation process to remove more TOC to reduce disinfection by-product precursors and enhance Stage 2 Disinfectants and Disinfection Byproducts Rule compliance.

PHOTOGRAPH: BIRMINGHAM WATER WORKS BOARD

Jeff Cochran observes differences in floc formation at the Birmingham (Ala.) Water Works Board's mobile pilot plant.

Figure 1. Pilot Plant Optimization Configuration

Two treatment trains allowed personnel to run plant-matching treatment on one train and optimized testing on the other train.



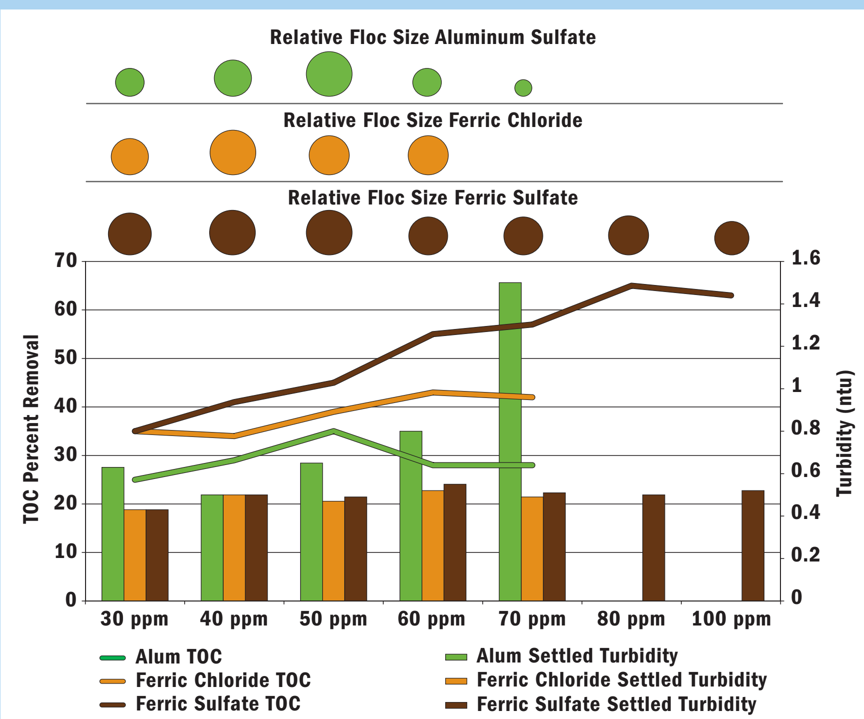
PILOT PLANT SETUP

The pilot plant contained two identical treatment trains, each containing a raw-water skid, flocculation–sedimentation skid, and filter skid. The identical treatment trains allowed personnel to run plant-matching treatment on one train and optimized testing on the other train. The approach also allowed personnel to negate pilot-plant-specific results if plant-matching train results matched full-scale plant results. Figure 1 illustrates the pilot plant's configuration for testing the coagulants' effect on settled water quality.

Floc formation was observed visually through windows in each flocculation basin in the pilot plant. By running baseline conditions on one train and optimization conditions on the other train, plant personnel could observe differences in floc formation in the two trains. As testing progressed, personnel compared coagulant doses with observed floc size differences. Next, personnel evaluated TOC removal and settled turbidity values associated with each coagulant dose and floc formation.

Figure 2. Relative Floc Size, TOC, and Settled Turbidity

Ferric sulfate significantly improved TOC removal, provided consistent floc formation, and reduced settled turbidity.



COAGULANTS

In addition to baseline testing of alum, testing included a proprietary ferric polyaluminum chloride (PACl) blend, ferric chloride, and ferric sulfate. Figure 2 plots measured floc size, percent TOC removal, and settled turbidity for the various coagulants. The size of the floc at various doses is represented by the size of the circles in Figure 2. Also in Figure 2, the line graph represents TOC, and the bar chart represents settled turbidities.

It should be noted that, because the final dose of lime was added on top of the filters, plant personnel decided to keep the coagulation pH at 6.0 or more to avoid significantly increasing head loss in the filters. Best performance for the coagulants was surprisingly similar, ranging between 6.0 and 6.4.

Alum. Although SMFP was already using alum and its capabilities were thought to have been maximized, testing was necessary to confirm TOC removal and settled turbidity levels, as well as to establish a baseline in the pilot plant. The baseline would provide a comparison point for future coagulant testing.

The pilot plant achieved maximum TOC removal of 35 percent with a 50-ppm dose of alum (Figure 2), which was close to dosing requirements and SMFP results. Plant personnel also observed an elevated trend in settled turbidity, which coincided with smaller observed floc size. As alum dosing was increased to 60 ppm and 70 ppm, the percent TOC removal decreased, and floc size decreased significantly, verging on pin floc.

Ferric Chloride/PACl Blend. Testing of a proprietary blend of ferric chloride/PACl

Since the coagulant changeover, SMFP has been able to attain greater than 70 percent TOC removal while maintaining settled turbidities well below 1.0 ntu through all seasons and water temperatures.

illustrated nearly identical responses in floc size, percent TOC removal, and settled turbidity values achieved with alum, with and without a coagulant aid. Because the ferric chloride/PACl blend performed so similarly to alum, its data aren't included in Figure 2.

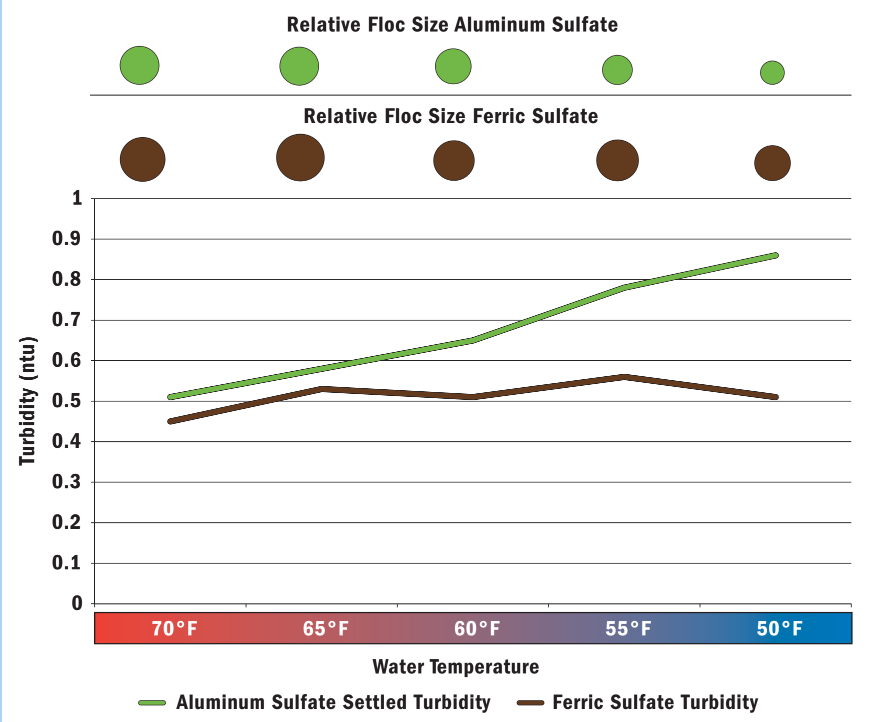
Ferric Chloride. Throughout testing, ferric chloride dosing maintained settled turbidity below 1.0 ntu without incident, with little variation, and without a coagulant aid (Figure 2). Interestingly, TOC removal didn't improve until a 50-ppm dose was tested, resulting in TOC removal as high as 45 percent with large stable floc. Because of concerns about release of metals into the distribution system—resulting from an interaction between chloride-based coagulant-treated water and sulfate-based coagulant-treated water at BWWB's three other plants—plant personnel halted 60-ppm testing at the pilot plant and turned their attention to ferric sulfate testing.

Ferric Sulfate. There was a significant difference in percent TOC removal between alum and ferric sulfate, starting shortly after a 40-ppm dose (Figure 2). Because alum's performance was drastically reduced with doses greater than 60 ppm, only data comparing doses up to 60 ppm are available. However, SMFP water has high enough alkalinity (80–100 mg/L as $CaCO_3$) to facilitate doses of ferric sulfate in excess of 100 ppm. There was drastic improvement in TOC removal, up to almost 70 percent with an 80-ppm dose, which was nearly double the percent removal achieved with alum. Also, relative floc size showed no serious reduction as dosing increased. Settled turbidity remained fairly constant at 0.5 ntu, well below the 1.0 ntu requirement. In addition, ferric sulfate showed no need for a coagulant aid.

Temperature Influences. Through two years of pilot plant use and testing, plant personnel observed that alum floc tends to get progressively smaller as temperatures decrease. To this point in testing, plant personnel had focused on warmer water (about 65°F). Figure 3 displays the results of testing alum to the best-performing ferric sulfate at various temperatures as water began to cool to 50°F. As expected, a reduction in alum floc size was observed as water temperatures decreased, but a reduction in ferric sulfate floc size was markedly less. Also as expected, settled turbidity values increased in cooler water for alum but remained constant for ferric sulfate.

Figure 3. Aluminum Sulfate vs. Ferric Sulfate

Ferric sulfate worked for a wider range of raw water conditions when compared with alum.



IMPROVED OPERATION

BWWB personnel concluded that ferric sulfate significantly improved TOC removal, provided consistent floc formation, and reduced settled turbidity. In addition, ferric sulfate worked for a wider range of raw water conditions when compared with alum. Much of the success of using ferric sulfate for TOC removal hinged on feeding 80–100 ppm, which was possible because of high levels of raw alkalinity. If raw water alkalinity were greatly reduced, ferric sulfate might not be the best choice. It would be difficult for ferric sulfate to improve alum's TOC removal at low alkalinities, because a higher dose of ferric sulfate was needed to increase TOC removal. The testing played a critical role in BWWB's decision to switch to ferric sulfate in the spring of 2009. Since the coagulant changeover, SMFP has been able to attain greater than 70 percent TOC removal while maintaining settled turbidities well below 1.0 ntu through all seasons and water temperatures.

***Editor's Note:** This article presents additional data from Birmingham Water Works Board's pilot-plant study, some of which were previously presented in Alabama Utility Puts Filter Media Performance to the Test,* Opflow, *March 2011.*